CHAPTER 10

DESIGN OPTIMIZATION

10-1. Design Optimization.

a. The project design life and design level of protection are required before the design conditions can be selected. The economic design life of most breakwaters and jetties is 50 years. Level of protection during the 50-year period is usually selected by an optimization process of frequency of damages when wave heights exceed the design wave and the cost of protection. The elements that are to be considered in an economic optimization or life cycle analysis are as follows:

(1) Project economic life.

(2) Construction cost for various design levels.

(3) Maintenance cost for various design levels.

(4) Replacement cost for various design levels.

(5) Benefits for various design levels.

(6) Probability for exceedance for various design levels.

b. The design level for a breakwater or jetty is usually related to wave characteristics and water levels. The severity of these events has a statistical distribution that can be ordered into a probability of exceedance. The exceedance probability is plotted against the design level (figure 10-1).

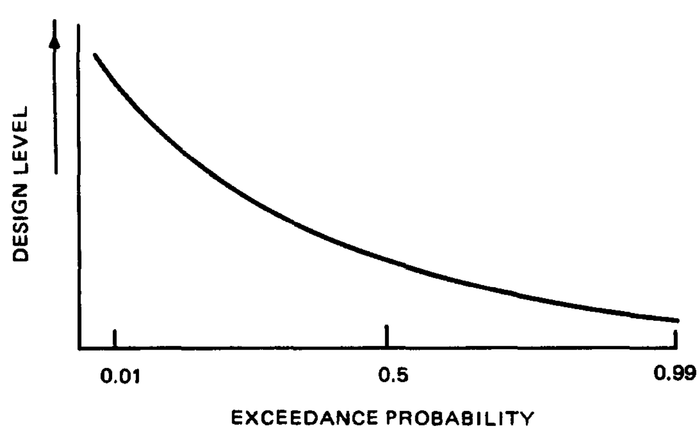

Figure 10-1. Exceedance probability versus design level

c. A series of project designs and cost estimates are developed for various design levels (water levels and wave heights). Construction costs are then converted to annual cost. Maintenance costs can be estimated by using table 4-4 and expected wave height exceedance frequencies illustrated in paragraph 4-17. This maintenance cost should be compared with maintenance of similar existing projects to assure realistic values.

d. Some designs may call for partial or total replacement of a project feature one or more times during the project economic life. Average annual replacement costs are obtained by estimating the replacement years, determining replacement cost and converting to present worth. The present worth value of the replacement is then converted to average annual cost by using appropriate interest rates and economic project life. The project cost curves usually look like those in figure 10-2.

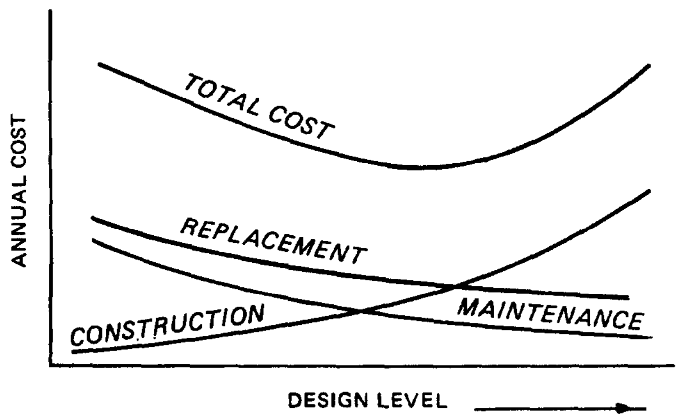

Figure 10-2. Project cost curves

e. Benefits are compared with cost to determine the optimum economic design. Figure 10-3 shows this benefit/cost comparison. Normally, the design level associated with the maximum net benefits will be selected for project design.

10-2. <u>Alternative Structures</u>.

a. The design process should include consideration of all alternative types of breakwaters which are suitable for the site conditions. These suitable alternatives can be:

(1) Various types of structures, such as floating or rubble-mound breakwaters.

(2) Alternative types of armor units for rubble-mound breakwaters.

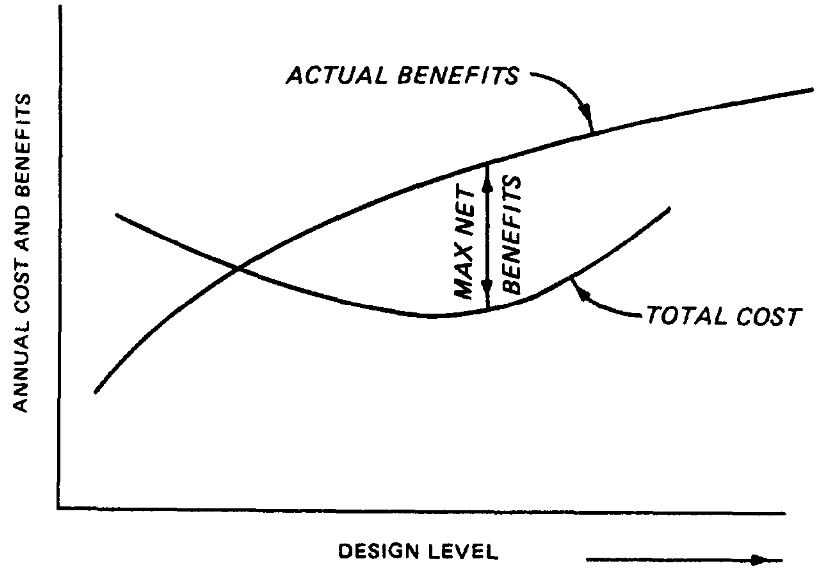

Figure 10-3. Benefits and cost versus design level

(3) "Overdesigning" rubble-mound armor units.

"Overdesigning" can greatly increase the factor of safety and reduce maintenance cost at no increase in cost. An example of this overdesign analysis is presented in item 141, where a comparison is made of dolos units which were designed for $K_D = 25$ (i.e., stable for design wave) and a second group designed for $K_D = 13.6$ (i.e., overdesigned). The following variables were used in this analysis:

Dolos stability coefficient = K_D = 25 and 13.6.

Structure slope = Cot α = 1.5, 2.0, 2.5, and 3.0.

Concrete unit weight = 150, 160, and 170 pounds per cubic foot.

b. Figure 10-4 shows the analysis for these variables based on rehabilitation cost for Humboldt jetty at Eureka, California, in 1970-72. The figure presents total first cost for 100 feet of structure as a function of dolos weight, structure slope, and concrete unit weight. Each point in the figure represents a solution to the design problem. One solution (Example 1 in figure 10-4), using the curves for $K_D = 13.6$, would be to construct the jetty with a slope of 1 on 2 of concrete with a unit weight of 160 pounds per cubic foot which requires a 5.2-ton dolos for armor against the 18-foot design wave. The cost for 100 feet of structure armored with a 5.2-ton dolosse is estimated at about $618,000. Another solution to the design problem (Example 2 in figure 10-4) would be to use a 7-ton dolos having a unit weight of 155 pounds per cubic foot placed on a 1-on-1.75 slope. The estimated cost of this solution per 100 feet of structure is $565,000.

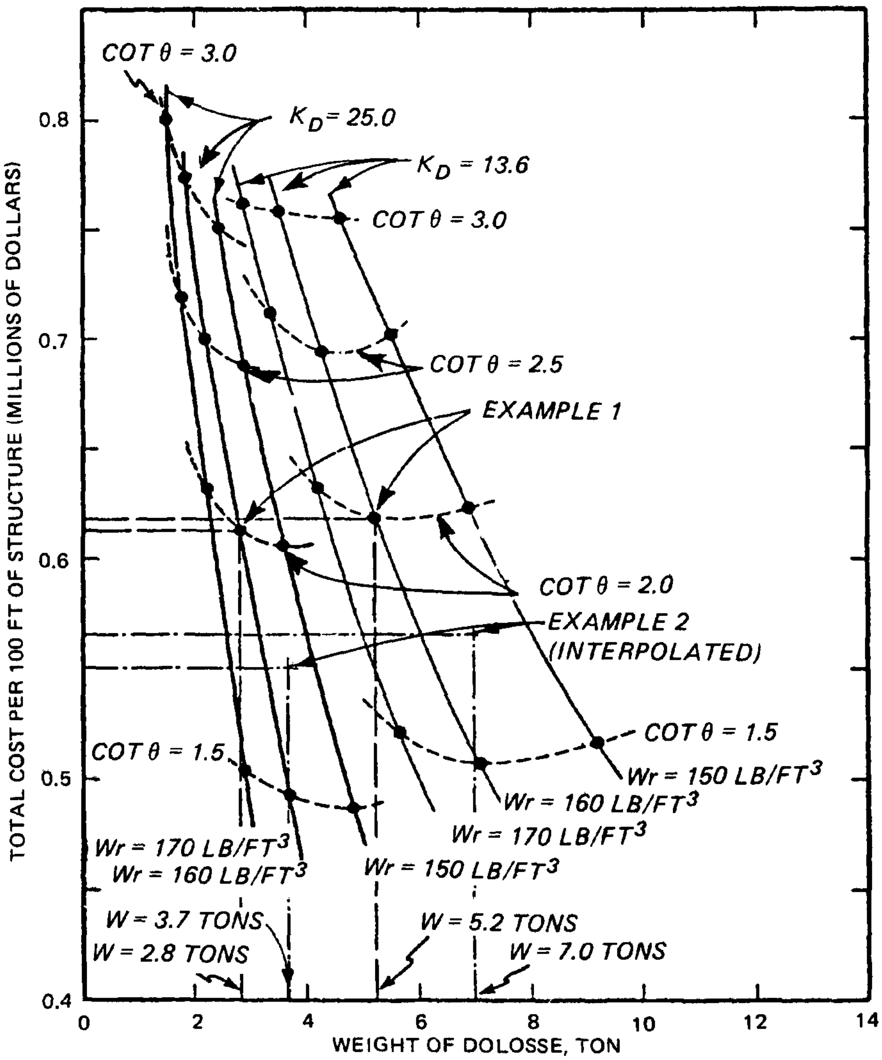

Figure 10-4. Total cost of 100 feet of structure as a function of structure slope, concrete unit weight, and dolosse weight for K_D = 13.6 and K_D = 25.0

c. When the stability coefficient is increased to K_D = 25.0 , the family of curves to the left in figure 10-4 represents solutions to the design problem. The required dolos weight has been nearly halved for equivalent conditions of structure slope and concrete unit weight. The cost per 100 feet of structure, however, has not changed appreciably; e.g., using K_D = 25.0 for conditions cited in Example 1 below with a structure slope of 1 on 2 and a concrete unit weight of 160 pounds per cubic foot, the required dolos weight has been reduced from 5.2 to 2.8 tons but the estimated cost has only decreased from $618,000 to $612,000 per 100 feet of structure. In Example 2, the required dolos is now only 3.7 tons rather than 7 tons but the estimated cost has only decreased from $565,000 to $550,000 (2.7 percent) per 100 feet.

In fact, for some conditions of structure slope and concrete unit weight the cost actually increases for the larger stability coefficient and smaller armor units. This generally occurs for flatter slopes and higher values of concrete unit weight.

d. The explanations for the relatively small change in cost with smaller armor units are that (1) the cost of the armor layer may represent a relatively small percentage of the total cost of the structure, especially for flat-sloped structures that have large quantities of core material, and (2) the relative cost of labor compared with the cost of materials used to construct armor units is high and results in an increase in the cost of armor. Labor costs in casting concrete armor units are sensitive to the number of units that need to be formed, stripped from forms, reinforced (if necessary), transported, and placed on the structure. The cost of materials, on the other hand, is simply proportional to the amount of materials needed. As the size of armor units decreases, the number of units required to cover a given structure surface area increases, and, along with it, the cost of labor to form, strip, reinforce, transport, and place the units; conversely, the amount of concrete, reinforcing, etc., required to cover a given area in armor will decrease with decreasing armor unit size. Whether or not a cost saving is realized by decreasing armor unit size depends on whether the savings achieved by using less materials exceed any increase in labor costs resulting from using more armor units. The relative cost of labor versus materials is thus an important factor in establishing the optimum size armor unit. As the relative cost of labor increases, it becomes more economical to design using fewer, larger units; i.e., overdesigning the armor.

e. It is recommended that designers of rubble-mound structures work closely with cost estimators to ensure that an optimum level of design is achieved. This can only be obtained if a range of design wave heights and corresponding structure designs is evaluated.